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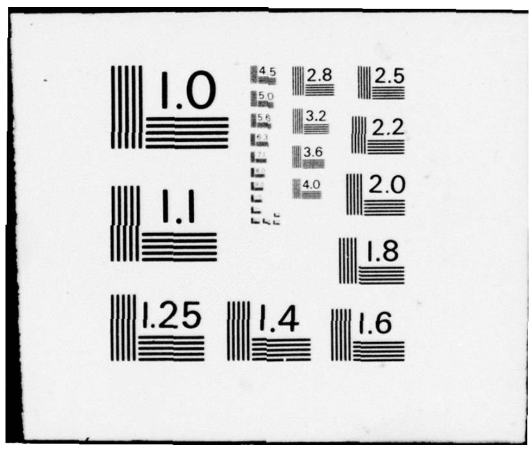
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Report No. CG-D-91-76

ICE BUOY DEMONSTRATION PROGRAM

Kenneth R. Bitting

June 1975

Final Report

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16. Abstract

The objectives of the ice buoy demonstration project, supporting the Great Lakes Season Extension Demonstration Program, were to test and evaluate modified standard Coast Guard aids-to-navigation buoys for use in the Great Lakes during the winter navigation season. Four standard lighted buoys were modified to increase survivability in the ice. They were: 5x18, 9x20, 9x32 and 9x38. One prototype buoy, a 16-foot-diameter octagonal disc buoy, was designed and fabricated especially for Great Lakes use. During the winters of FY73, FY74 and FY75, these buoys were deployed at key locations in the Great Lakes. The buoys were photographed by Coast Guard air and water craft and mooring line tensions were recorded. The success of a buoy/mooring is a function of both the buoy shape and ice conditions at the deployment location. The 9x38 and 9x32, the 9x20 and the 5x18 buoys are overrun by moving ice that is 8 to 10 inches thick, 6 inches thick and 4 to 6 inches thick, respectively. The 16-foot diameter octagonal buoy was not submerged by moving ice but does show a tendency to list under the influence of ice on the deck.

When a buoy is submerged, lantern damage generally occurs. High holding power anchors must be used (9000-pound STATO anchor and 12,750-pound concrete sinker) to hold the 9x20, 9x32, 9x38 and 16-foot diameter octagonal buoy on station with some reliability. The 5x18 buoy can be moored with a 12,750 pound concrete sinker.

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Ice buoys, winter navigation, Great Lakes navigation, Great Lakes Season Extension Demonstration Program

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1.0 INTRODUCTION

In FY73, the Coast Guard Research and Development Center was tasked with supporting the Great Lakes Season Extension Demonstration Program which had as its objective the demonstration of the feasibility of making the Great Lakes navigable for the greater portion of the winter. The Research and Development Center managed the Ice Buoy Demonstration Program which was undertaken to demonstrate the feasibility of using lighted buoys as an effective aid to navigation for the mariner during the winter navigation season. To this end, four standard Coast Guard aids-to-navigation buoys, the 5x18, 9x20, 9x32 and 9x38 were modified to increase survivability in ice conditions. An additional buoy, a 16-foot diameter octagonal prototype was designed and fabricated especially for Great Lakes winter use. The hull modifications of the standard buoys are shown in Appendix A as well as the 16-foot prototype design.

In mid-winter, many of the navigational aids in the Great Lakes are frozen fast. Navigational buoys generally survive this period. The ice in the navigation channels is broken by an icebreaker to allow commercial vessels to pass. In most cases, the track does not move because the surrounding ice is frozen to the shore. The most critical period, however, occurs in the spring when the fast ice begins to break up and flow. The track previously broken by the icebreaker moves under the influence of wind and current and can no longer be followed safely. Buoys deployed in exposed areas are generally overrun or pulled off station by the moving ice.

1.1 Program Objectives

The ice buoy demonstration project has the following objectives:

a. Determine how each buoy hull shape reacts to ice, the ice thickness that limits buoy performance because of damage or submersion, and the damage incurred.

b. Determine the mooring requirements for each buoy type.

c. Determine the feasibility of using buoys in ice conditions.

1.2 Background

1.2.1 FY73 - The R&D Center became involved in the ice buoy demonstration program in January 1973. The buoys had been deployed by the Ninth Coast Guard District at the locations in Appendix B under the supervision of Coast Guard Headquarters. The ice conditions that year were very mild, and limited results were obtained.

1.2.2 FY74 - Ice buoy deployments were divided into two categories: (a) operational, and (b) observational.

1.2.2.1 Operational Ice Buoys - The operational ice buoys were deployed as functional aids-to-navigation buoys for use by the mariner. The buoys were photographed by Coast Guard vessels that transited the area and by Coast Guard ice reconnaissance flights. Ice conditions at the time were recorded. Darkness, poor visibility, low frequency of observations, and passing too far from the buoy acted to limit data gathered

by this method. Considerable ice activity may also occur between photographing opportunities. However, excellent and timely photographs were obtained which contributed significantly to the understanding of ice buoy performance. Photographs obtained by ships and helicopters were of equal quality and usefulness and served to overlap coverage. Substantial information was collected regarding the performance of 9x38, 9x32 and 5x18 ice buoys. No conclusive information was collected, however, on the 16-foot-diameter octagonal buoy or the 9x20 buoy. Mooring line tensiometers were placed in the mooring to record the mooring forces caused by the ice force on the buoy.

1.2.2.2 Observational Buoys - One of each type of buoy was deployed near Detour Reef Light Station at the lower end of the St. Mary's River. In this way, the four buoys would be subject to the same ice conditions and the performance of each could be compared directly to the others. The buoys were observed and recorded on video tape. The success of this operation was subject to a combination of factors (ice conditions, location, accessibility, time response of video crew) which operated to minimize the quality and quantity of the data obtained. A video tape crew was on Detour Reef Light Station from 1 to 6 April 1974, during which time ice movement was expected but did not occur. The ice movement that was recorded was insignificant.

1.2.3 FY75 - All ice buoys were deployed as operational aids. Emphasis was placed on the lower Great Lakes area (Lake Huron and Lake St. Clair) where rapidly moving ice causes damage to ice buoys and the great distance to shore reduces the efficiency of fixed aids. The buoys were photographed by Coast Guard vessels as they transited the area, and ice conditions were recorded at the time the photographs were taken. Information was collected that substantiated observations made during FY74. In addition, information was collected on the performance of the 16-foot-diameter octagonal and 9x20 buoys.

2.0 BUOY HULL PERFORMANCE

2.1 9x32 and 9x38

These buoys are submerged by eight to ten inches of moving ice. Lanterns are generally lost (Figure 1), and the battery pockets have been ripped open and flooded on occasion (Figure 2). On some areas of the hull, paint was scraped off to the primer or bare metal. Reports from mariners indicate that the buoy can be more difficult to identify if the ice scrapes off the red paint and reveals the dark primer. The characteristic color, therefore, changes. The deep hull of the 9x32 ice buoy presents a large vertical surface to the ice. As the ice pressure increases, the buoy lays over and the hull submerges until just the lantern and pole are above the ice (Figure 3). In thin ice (six to eight inches thick) this appears to be the stable position. In thicker ice (eight to ten inches) the ice force on the hull is too great and the pole and lantern go under the ice. The advantage of the 9x32 and 9x38 buoys is a large reserve buoyancy (16,000 pounds).

Mariners have suggested that the buoy hull primer and paint be the same color so that, as the ice scrapes off the paint and exposes the primer, the buoy does not change its characteristic color. Reflective tape should be used to increase night visibility. These observations apply to all buoy hulls.

2.2 9x20

Photographs indicate that the 9x20 is overrun by ice that is approximately six inches thick. It appears to lack the ballast to compensate for the ice force on the hull. Figure 4(a) shows a 9x20 as photographed when it was abeam of a ship that was moving parallel to the ice flow. The buoy is listing approximately 45°. In Figure 4(b), looking back at the buoy after the ship passed, the buoy appears to be on its side. In a third frame (not shown), the buoy has disappeared and only the wake is visible. In Figure 5, ice has filled the lantern cage and snow covers the entire deck. A subsequent photo (not shown) shows the lantern destroyed but the cage undamaged.

2.3 5x18

Before ice forms on the river, 5x18 buoys have been observed floating horizontally with large quantities of spray ice on the upper portion (Figure 6). The 5x18 is submerged by four to six inches of ice (Figure 7), and the lantern is generally broken. It has been observed upright in as much as fourteen inches of ice, however. One buoy was under the ice in the St. Lawrence Seaway for 45 days and was functioning upon recovery.

2.4 16-Foot-Diameter Octagonal Buoy

During FY73 and FY74, this buoy was deployed in locations where moderate ice conditions were encountered. Approximately twelve inches of ice and snow collected on the deck causing the buoy to list approximately 15° (Figure 8). During FY75, it was deployed at East Outer Channel LB1 (Detroit), where it was exposed to thick and fast-moving ice. The buoy functioned well at this location except for one notable exception. In January 1975, the buoy was reported 1000 yards from charted position. The bottom is reported on charts and Simplified Aids-to-Navigation Data System (SANDS) reports as clay and soft, respectively. The anchor is assumed to have been silted in. The buoy deck was reported to be so covered with ice and snow that it caused the buoy to list approximately 80°. The light was approximately one foot from the ice. It is theorized that, with the buoy listing so badly, the large flat bottom presented a large area to the ice, allowing for high ice forces. The buoy may have been dragged across the anchor, causing the anchor to tumble out. At that time, the ice thickness was two to five inches with rafting up to two feet. The buoy was reset using the original 9000-pound STATO anchor and 12,750-pound concrete sinker plus a 10,000-pound ship's anchor. The original mooring had been in place from 22 December 1973 to 23 January 1975, although previous ice buoys had been attached to it.

3.0 MOORING PERFORMANCE

3.1 9x32 and 9x38

This size buoy cannot be moored reliably without a high holding power anchor. Lake Huron Cut LB11 (FY74) dragged an 8,500 and 12,750 pound concrete sinker about nine miles. The tensiometer on Round Island LB32

occasionally recorded mooring line tensions of 20,000 to 30,000 pounds. Figure 3 shows Round Island LB32 under approximately eight inches of moving ice. Tensiometer readings of 18,000 to 22,000 pounds were recorded during this period. Since the reserve buoyancy is 16,000 pounds and the angle of the lantern from the vertical has been measured (from photographs) at 45 to 55°, it is calculated that tensiometer readings in that range would indicate that the buoy hull may be under the water.

3.2 9x20

Lime Island Traffic Buoy (FY74) is the only 9x20 for which tensiometer data was obtained. The recording indicates that the mooring line tension was approximately 18,000 pounds on several occasions and reached 30,000 pounds on two occasions. The reserve buoyancy of this buoy is 6,900 pounds. Lack of buoy damage, however, indicates that the buoy probably was not under the ice.

3.3 5x18

This buoy can be moored with a 12,750 pound concrete sinker. It is theorized that this buoy is generally overrun by ice before high mooring forces are generated. No tensiometer data was collected.

3.4 16-Foot-Diameter Octagonal Buoy

This buoy can be moored with a 9,000 pound STATO anchor and 12,750 concrete sinker. This mooring has worked well with the exception noted above.

4.0 SUMMARY OF OBSERVATIONS

Although a vast amount of information was accumulated during the three ice seasons that this demonstration was conducted, firm conclusions can be drawn in several areas only.

a. 9x38 and 9x32 - Ice, atmospheric and bottom conditions as well as hull shape determine the ultimate performance of an ice buoy. A buoy which will stand upright while ice is forming must have large reserve buoyancy to withstand the forces generated by moving ice, with the premise that the mooring configuration will hold it on station. From the reports compiled by Coast Guard vessels, air reconnaissance and commercial vessels, it appears that the 9x38 and 9x32 buoys perform adequately when moored with a 12,750-sinker and 9000-pound STATO anchor. At certain times they were overrun by 8 to 10 inches of moving ice, resulting in damage to paint, lantern and battery covers. Critical ice velocities were not determined. Line tensions up to 30,000 pounds were recorded without moving the buoy off station.

b. 9x20 - The same premise for (a) above holds true for this buoy. The hull shape of the 9x20 is such that the ice tends to ride under it with the body listing due to icing on the top and lantern pole. The mooring with a 12,750-pound concrete sinker and a 9000-

pound STATO anchor will probably provide enough holding power to prevent the buoy from moving off station under moving ice conditions but the buoy could be overrun by 6 inches of ice. Performance is generally adequate.

c. 5x18 - The upper buoy body and lantern pole become covered with spray ice under adverse wind and temperature conditions before surface ice has formed. This condition causes the buoy to list considerably. The 5x18 is generally submerged by 4 to 6 inches of moving ice. It can be moored with a 12,750-pound concrete sinker but will suffer paint and lantern damage generally in all but the lightest ice conditions. This buoy is generally not adequate for ice season use.

d. 16-foot Octagonal Buoy - This buoy performed well in most conditions. A non-symmetrical accumulation of ice tends to make it list excessively although it still performs as an effective aid to navigation. An exception to its performance over the three seasons was in January 1975 when it was dragged some 1000 yards off its charted position. After being reset with an additional 10,000-pound ship's anchor it remained on station until recovered.

5.0 CONCLUSIONS AND RECOMMENDATIONS

(1) The ice buoys investigated in this report have limited utility in the Great Lakes; the degree of success is highly site-dependent.

(2) Buoys can remain on station when moored with high holding power anchors and high strength chain.

(3) The success of an ice buoy is highly dependent on the ice conditions at a specific location where it is deployed. It is likely that, at specific locations, there is no design that can both remain above ice and on station in moving ice conditions.

(4) Buoy hull configuration has a great affect on a buoy's ability to withstand excess accumulation of ice on the upper structure and subsequent ice forces acting on the lower hull.

(5) Improved lantern protection should be provided to eliminate lantern damage when the buoy goes under the ice.

(6) Battery pocket covers should be made flush with the hull if practicable.

(7) The buoy hull paint primer should be the same color as the paint.

(8) Reflective tape should be used on all buoys to increase night visibility.

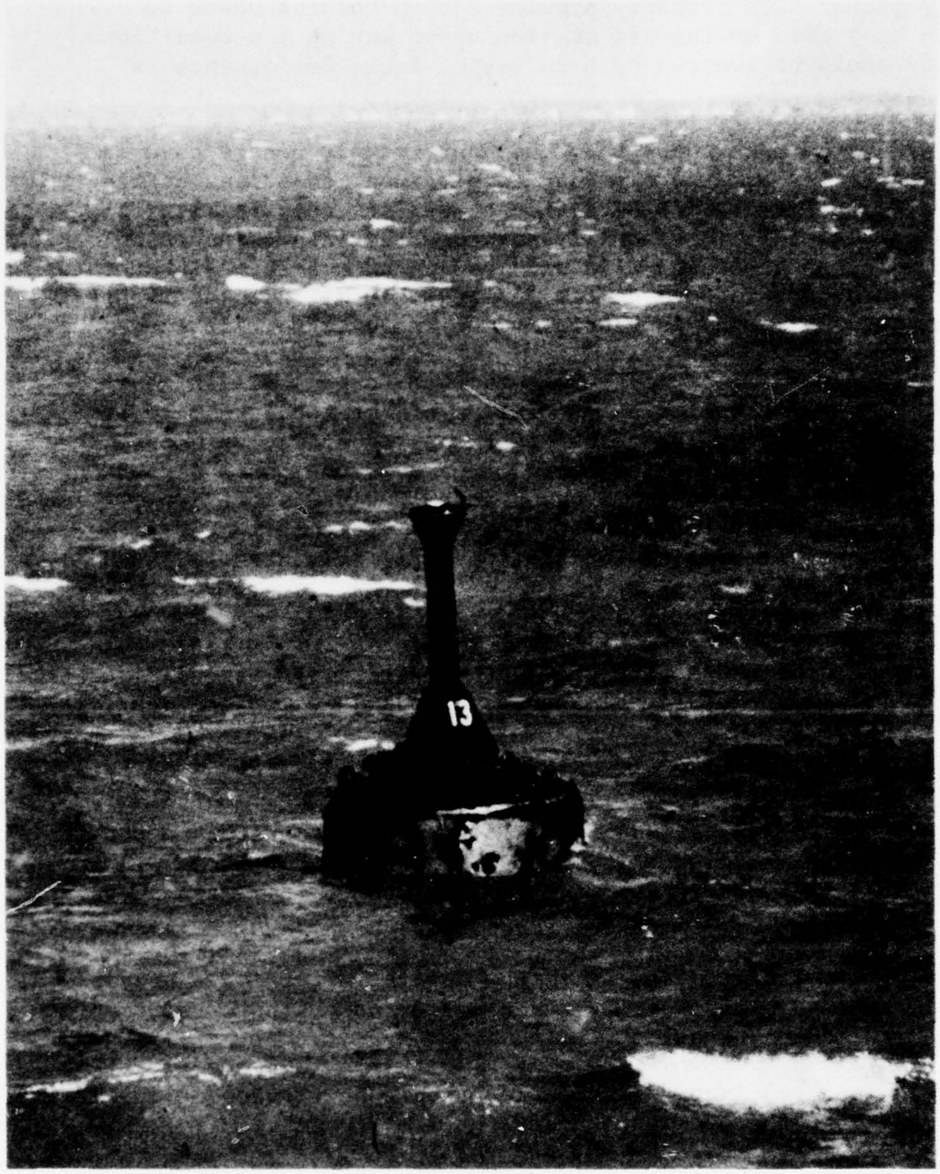


Figure 1. 9x32 ice buoy with lantern and paint damage (Lake St. Clair LB13 - FY74).

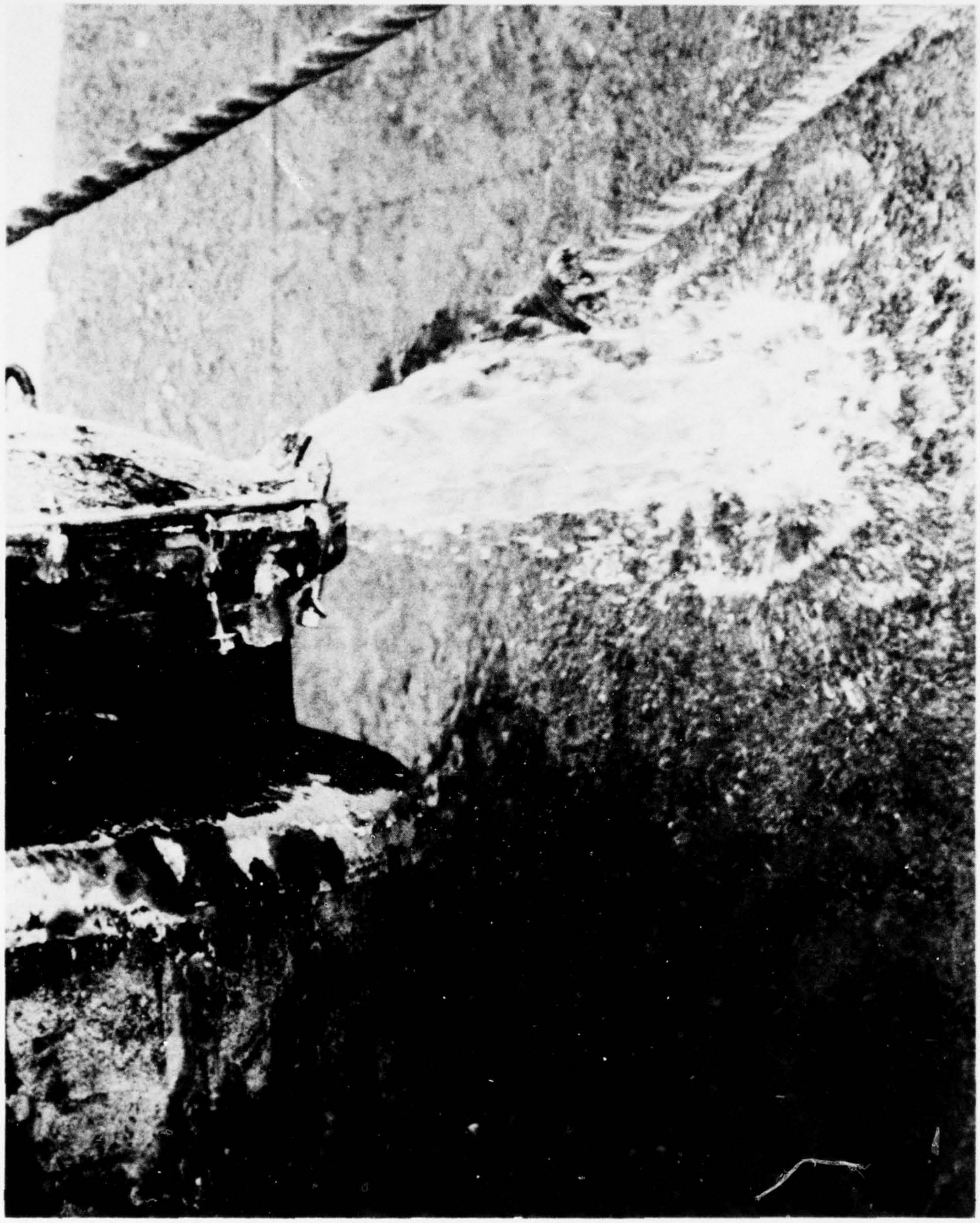


Figure 2. Battery pocket damage on 9x32 ice buoy
(East Outer Channel LB1 - FY74).

Figure 3. 9x38 ice buoy under 8 inches of moving ice (Round Island LB32 - FY74).

4(a)

4(b)

Figure 4. 9x20 ice buoy under ice.

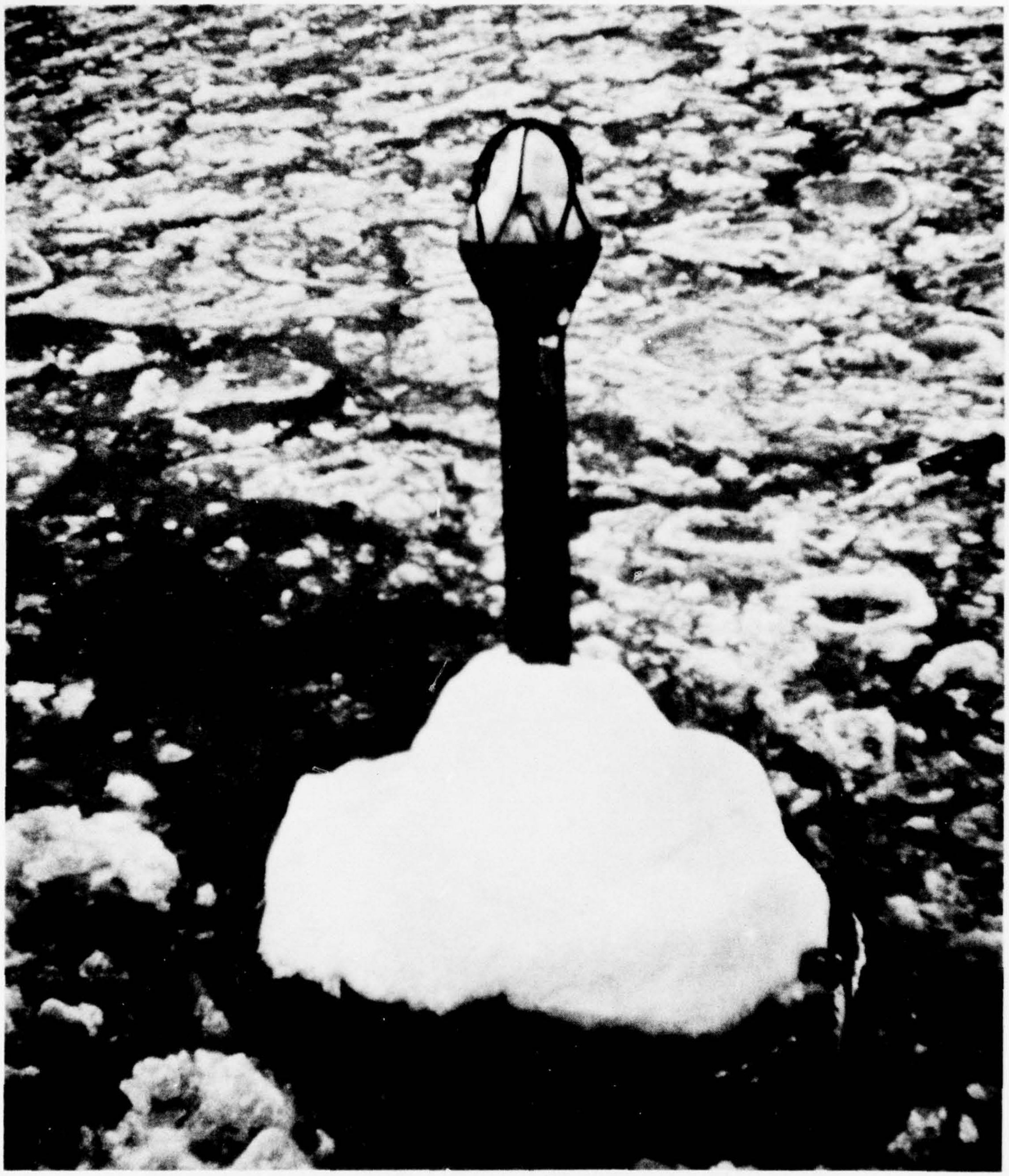


Figure 5. 9x20 ice buoy with ice in lantern case.

Figure 6. 5x18 ice buoy with spray ice.

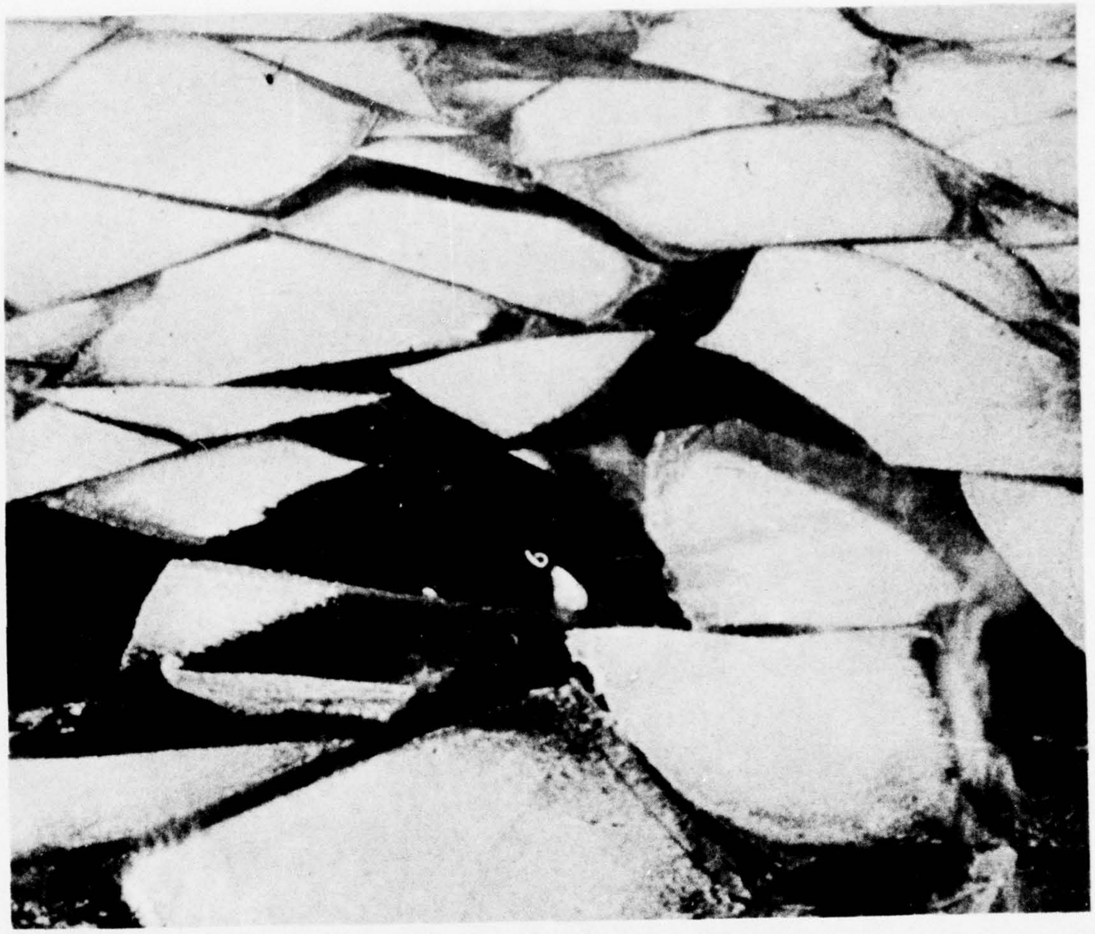
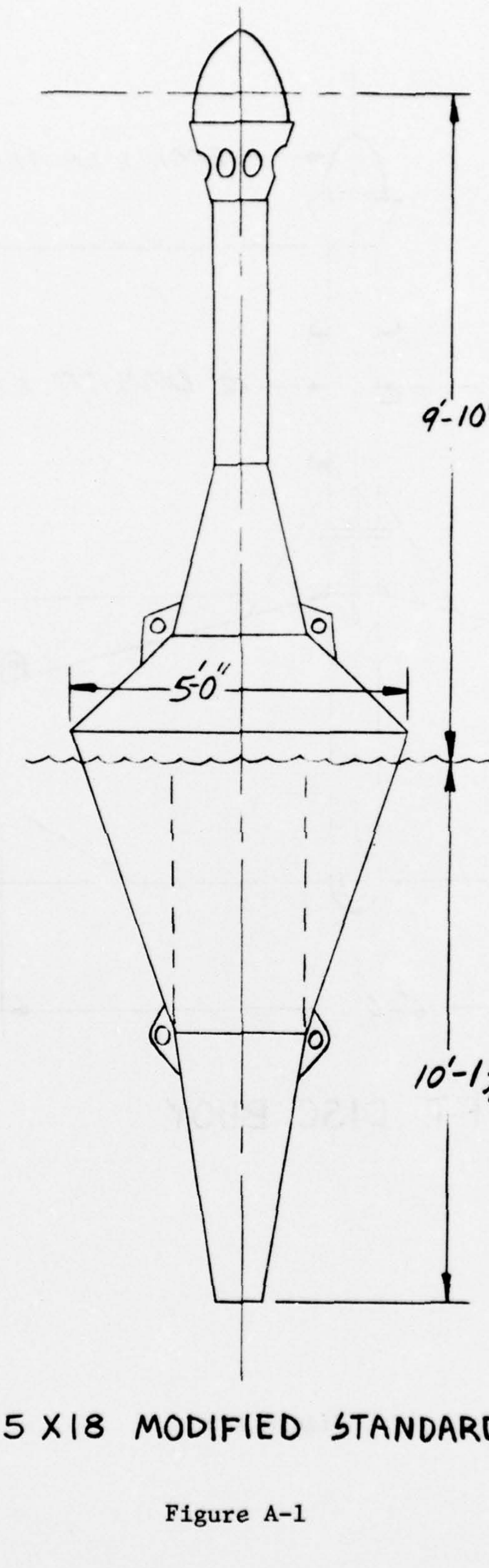


Figure 7. 5x18 ice buoy in 6 inches of moving ice.

Figure 8. 16-foot-diameter octagonal ice buoy with ice and snow on deck (Detour Reef Light Station - FY74)

APPENDIX A

ICE BUOY HULL DESIGN



5 X18 MODIFIED STANDARD BUOY

Figure A-1

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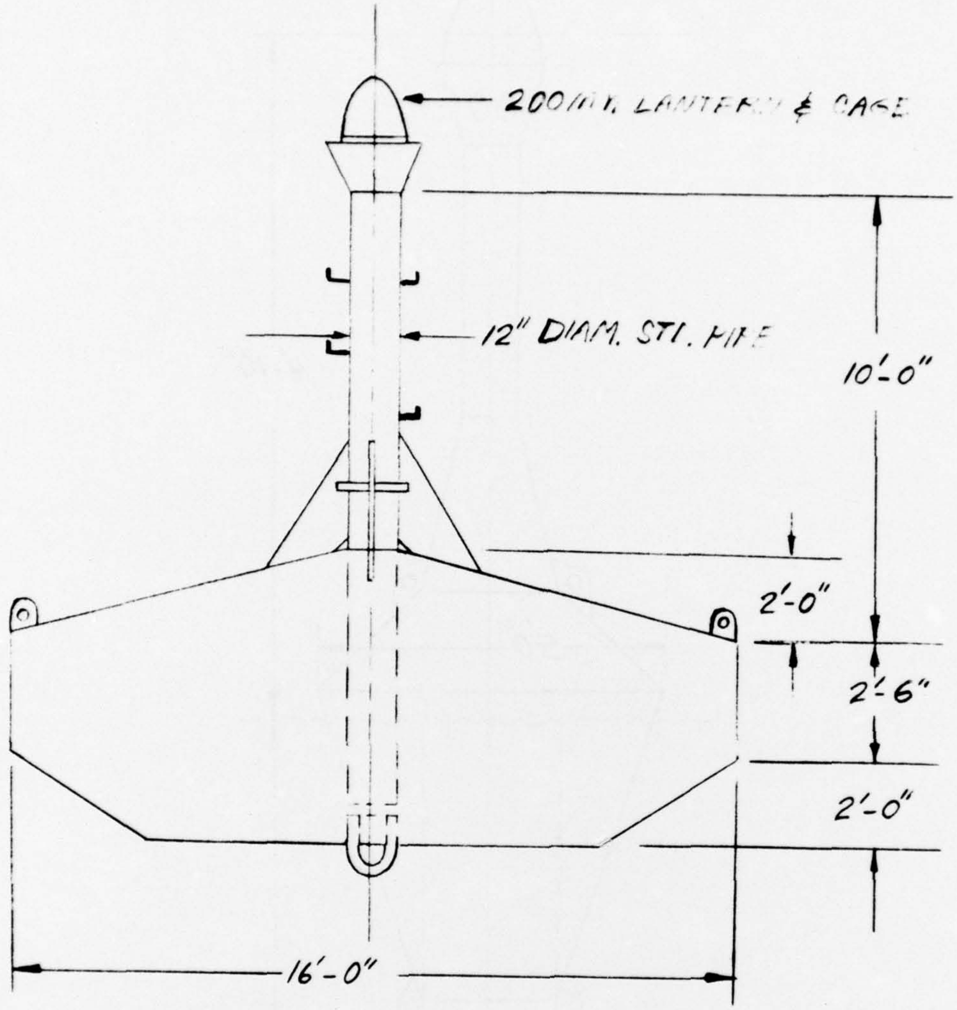
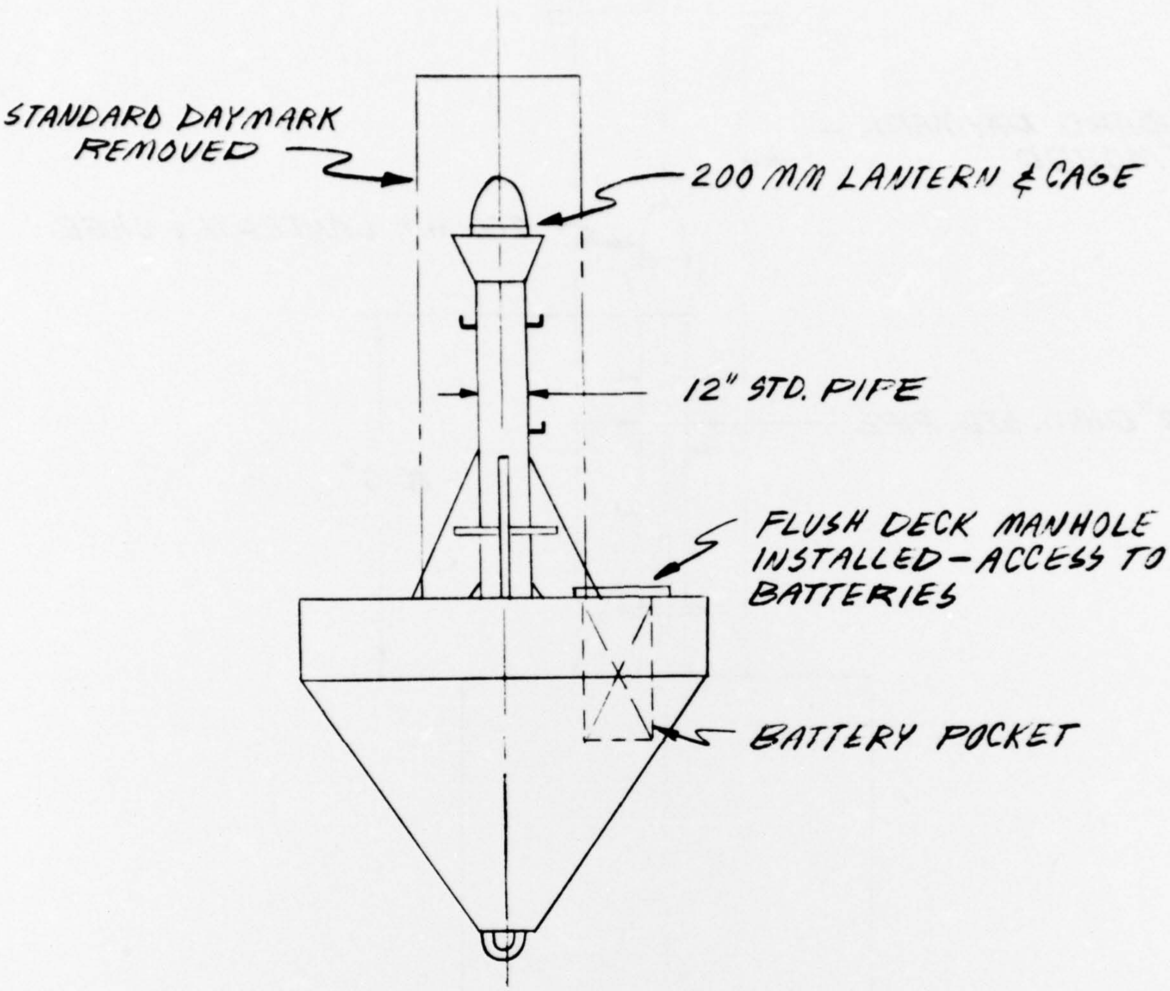


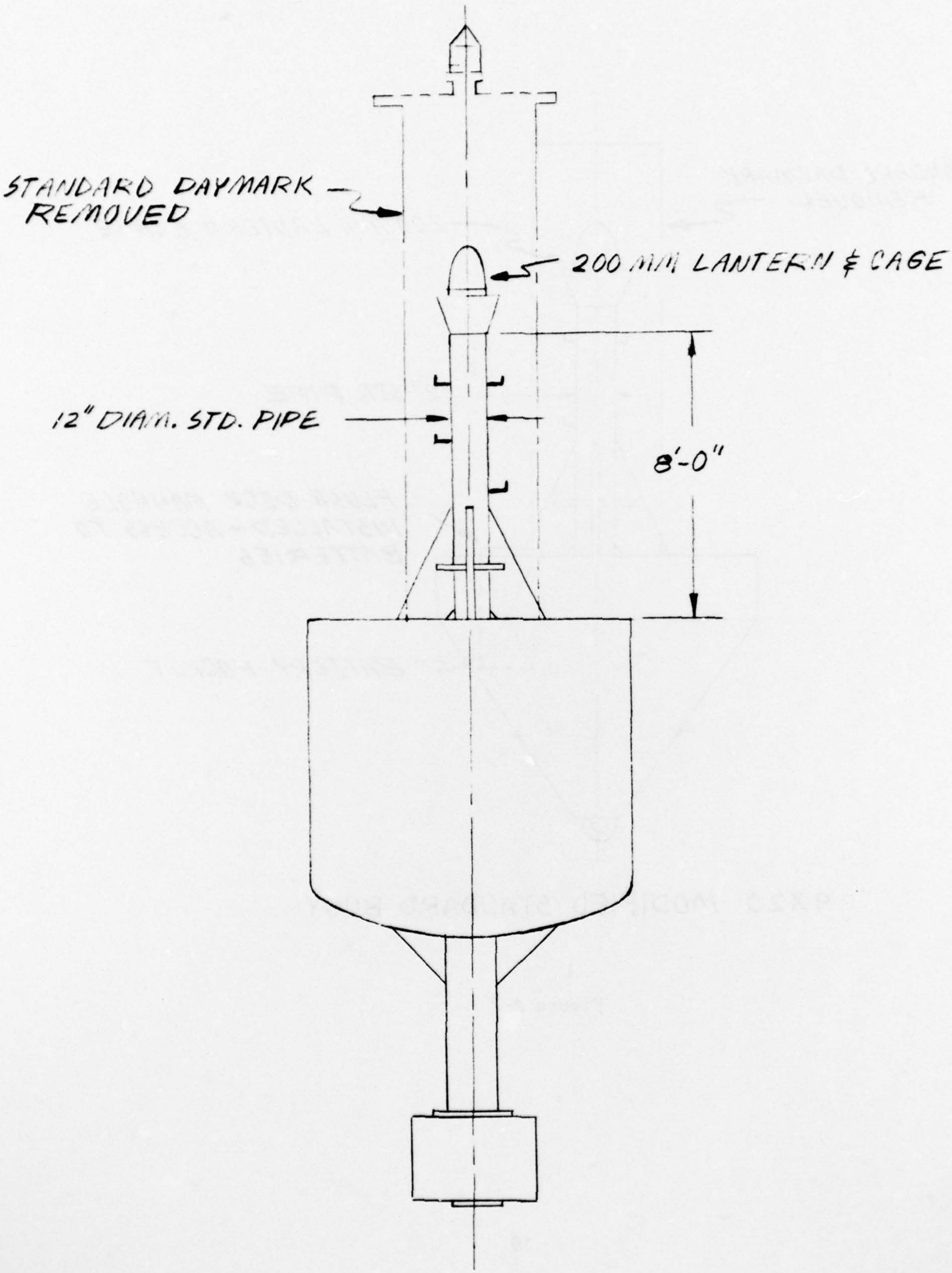
16 FT DISC BUOY

Figure A-2



9X20 MODIFIED STANDARD BUOY

Figure A-3



9x32/38 MODIFIED STANDARD BUOY

APPENDIX B

ICE BUOY MOORING CONFIGURATION AND DEPLOYMENT LOCATION - FY73

ICE BUOY DEPLOYMENT - FY73

AID	DEPTH	BUOY TYPE	CHAIN TYPE	MOORING CONFIGURATION	ANCHOR(S)
1. Lake Munuscong Junction LBB (LL 1478)	19'	9X32L	1 1/2" stud Link - 83'	18' 1 1/2" buoy bridle to 1 1/2" swivel, 7' chain to 3rd class shackle connected to tensiometer to 3rd class shackle, 61' of chain to 3rd class shackle to 12,000# cnncrete sinker, 15' of chain 2nd class shackle to 9,000# stato anchor.	12,000# concrete sinker 9,000# stato anchor
2. Lime Island Traffic Buoy (LL 1459)	52'	Special 16' dia. Octaganol Buoy	1 1/2" stud Link - 97'	Same as 9x32 except no bridle was used as connection was made under center of buoy	12,000# concrete sinker 9,000# stato anchor
3. Little Rapid Cut Lighted Buoy 104 (LL 1594)	26'	5x18L	1 1/8" Stand-ard Chain - 50'	No bridle 3rd class shackle connecting buoy to 40' chain, to 3rd class shackle to 4,200# iron sinker 10' connecting with 3rd class shackle to 12,000# sinker	12,000# concrete sinker 4,200# iron sinker
4. Lake Nicolet Lighted Buoy 77 (LL 1523)	25'	5x18L	1 1/2" stand-ard Chain - 50'	Same as Little Rapid Cut Lighted Buoy 104 (LL 1594)	12,000# concrete sinker 4,200# iron sinker
5. Round Island LB #32	23'	9x20L	1 1/2" stud Link	18' 1 1/2" buoy bridle, tensiometer 45' 1 1/2" chain, sinker 10' above bottom 180' chain to anchor	12,000# concrete sinker 9,000# stato anchor

APPENDIX C

ICE BUOY MOORING CONFIGURATION

AND DEPLOYMENT LOCATION - FY74

ICE BUOY DEPLOYMENT - FY74

AID	DEPTH	BUOY TYPE	CHAIN TYPE	MOORING CONFIGURATION	ANCHOR(S)
1. Lake Huron Cut LB 11 (LL 1230)	22'	9x32L	1 1/2" stud Link	Tensiometer, 1 1/2"x15' bridle, 48' 1 1/2" chain	12,750# concrete sinker
2. Lake St. Clair LB 13 (LL 1033)	15'	9x32L	1 1/2" stud	Tensiometer, 1 1/2"x18' bridle, 48' 1 1/2" chain to sinker	12,750# concrete sinker
3. Detroit East Outer Channel LB 1 (LL 851.10)	28'	9x32L	1 1/2" stud	Tensiometer, 1 1/2"x18' bridle, 90' to sinker to 60' to stato anchor	12,750# concrete sinker 9,000# stato anchor
4. Lake Munuscong Junction LB (LL 1478)	19'	9x32L	1 1/2" stud Link	Tensiometer, 1 1/2"x18' bridle, 120' 1 1/2" chain to sinker, 90' 1 1/2" chain to stato anchor	12,750# concrete sinker 9,000# stato anchor
5. Round Island LB 32 (LL 1638)	23'	9X32L	1 1/2" stud Link	Tensiometer, 1 1/2"x18' bridle, 70' 1 1/2" chain, (distance between bridle, sinker, stato anchor not specified)	12,750# concrete sinker 9,000# stato anchor
6. Lime Island LB (LL 1459)	52'	9x20L	1 1/2" stud Link	Tensiometer, 1 1/2"x18' bridle, 120' 1 1/2" chain	12,750# concrete sinker
7. Munuscong Channel LB6 (LL 1481)	23'	5x18LI	1 1/2" stand-ard chain	42' 1 1/4" chain	6,500# concrete sinker
8. Lake Huron Cut LB8 (LL 1227)	22'	5x18LI	1 1/2" stud Link	48' 1 1/2" chain	12,750# concrete sinker
9. Munuscong Channel LB8 (LL1482)	21'	2NR	7/8" stand-ard	48' 7/8" chain	8,500# concrete sinker

ICE BUOY DEPLOYMENT - FY74 (Cont'd)

AID	DEPTH	BUOY TYPE	CHAIN TYPE	MOORING CONFIGURATION	ANCHOR(S)
10. Lake St. Clair LB14 (LL 1034)	13'	1NR	1 1/8" standard	48' 1 1/8" chain to sinker 30' 1 1/8" chain to 2nd sinker/ reset 1/17/74 with 90' 1 1/2" chain to sinker 50' 1 1/2" to 2nd sinker	2 ea. 8,500# concrete sinker
11. Lake St. Clair LB30 (LL 1044)	13'	1NR	1 1/8 standard	48' 1 1/8" chain	8,500# concrete sinker
12. Lake St. Clair LB29 (LL 1043)	13'	2CR	1 1/8" standard	(No report)	8,500# concrete sinker
13. DeTour Reef Buoy Farm (450' 210°T from DeTour Reef LT)	38' (approx.)	16' dia. octagonal	1 1/2" stud Link	No bridle, 12' to tensiometer 98' to sinker 65' to stato anchor	12,750# concrete sinker 12,000# stato anchor
14. DeTour Reef Buoy Farm (350' 230°T from DeTour Reef LT)	30' (approx.)	9x38L Ice Modified	1 1/2" stud Link	1 1/2" bridlex18', 10' 1 1/2" chain to tensiometer, 105' to sinker, 90' between sinker and stato	12,750# concrete sinker 9,000# stato anchor
15. " (300' 255°T from DeTour Reef LT)	30' (approx.)	9x20L Ice Modified	1 1/2" stud Link	1 1/4"x15 bridle, tensiometer 70' 1 1/2" chain (location of tensiometer not reported)	12,750# concrete sinker
16. DeTour Reef Buoy Farm (350' 280°T from DeTour Reef LT)	30' (approx.)	1NR	1 1/4" standard	70' 1 1/4" chain to sinker	12,750# concrete sinker

ICE BUOY DEPLOYMENT - FY74 (Cont'd)

AID	DEPTH	BUOY TYPE	CHAIN TYPE	MOORING CONFIGURATION	ANCHOR(S)
17. DeTour Reef Buoy Farm (450' 300°T from DeTour Reef LT)	30' (approx.)	5x18L	1 1/2" stud Link	70' 1 1/2" chain to sinker	12,750# concrete sinker

APPENDIX D

ICE BUOY MOORING CONFIGURATION

AND DEPLOYMENT LOCATION - FY75

ICE BUOY DPLOYMENT - FY75

AID	DEPTH	BUOY TYPE	CHAIN TYPE	MOORING CONFIGURATION	ANCHOR(S)
1. Round Island LIB 32 (LL1638)	23'	9x38LI	1 1/2" stud Link	1 1/2"x18 bridle, tensiometer (No report)	12,750# concrete sinker 9,000# stato anchor
2. Lake Munuscong Junction LIB (LL1478)	19'	9x32LI	1 1/2" stud Link	1 1/2"x18 bridle (No report)	12,750# concrete sinker 5,000# ship anchor
3. Munuscong Channel LIB6 (LL1481)	23'	5x18LI	1 1/4" stand-ard	(No report)	12,750# concrete sinker
4. Lake St. Clair LIB13 (LL1033)	15'	9x32LI	1 1/2" stud Link	1 1/2"x18' bridle, tensiometer (No report)	12,750# concrete sinker
5. Lake Huron Cut LIB11	22'	9x38LI	1 1/2" stud Link	1 1/2"x18' bridle, tensiometer 50' 1 1/2" chain to sinker 90' chain to second sinker	12,750# concrete sinker 8,500# concrete sinker
6. Lake Huron Cut LIB8 (LL1227)	23'	9x20LI	1 1/2" stud Link	1 1/4" x 15' bridle (No report)	12,750# concrete sinker 5,000# ship anchor
7. Lake St. Clair LIB29 (LL1043)	13'	9x20LI	1 1/2" stud Link	1 1/4" x 15' bridle (No report)	12,750# concrete sinker 5,000# ship anchor
8. Maumee Bay Entrance LIB2 (LL745)	22'	9x20LI	1 1/4" stand-ard	1 1/2" x 18' bridle, 60' 1 1/4" chain to sinker 90' 1 1/8" to anchor	12,500# concrete sinker 1,400# anchor
9. Lime Island Traffic LIB (LL1459)	52'	9x38'LI	1 1/2" stud Link	1 1/2" x 18' bridle tensiometer (No report)	12,750# concrete sinker 9,000# stato anchor

ICE BUOY DEPLOYMENT - FY75 (Cont'd)

AID	DEPTH	BUOY TYPE	CHAIN TYPE	MOORING CONFIGURATION	ANCHOR(S)
10. East Outer Channel LIB1 (LL851.10)	28'	16' dia. octagonal	1 1/2' stud Link	1 1/2"x18' bridle, 60' to sinker 90' to stato anchor (tensiometer in first 60' chain length) 60' 1 1/2" chain from sinker to stockless anchor	12,750 concrete sinker 9,000# stato anchor 10,000# stockless anchor
11. East Outer Channel LIB14 (LL856)	21'	9x20LI	1 1/2" stud Link	1 1/4" x 15' bridle, tensiometer 60' 1 1/4" chain to sinker 80' 1 1/4" chain to stato anchor	12,750# concrete sinker 9,000# stato anchor

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